

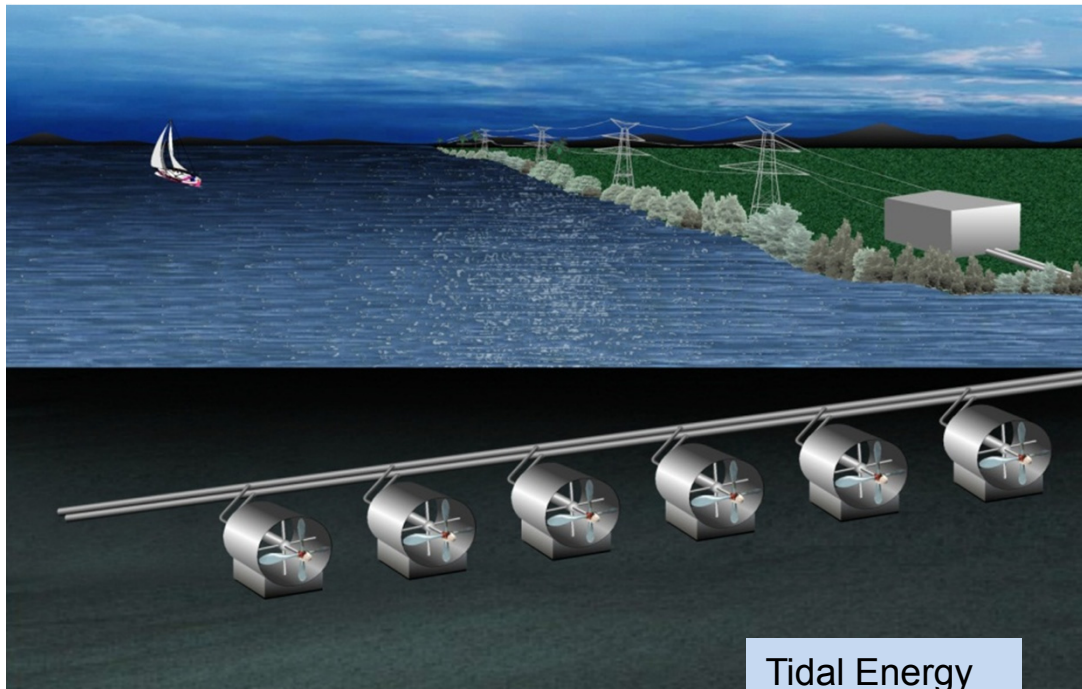
On-Shore Central Hydraulic Power Generation for Wind and Tidal Energy



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DOE Marine and Hydrokinetic Technology Readiness Advancement Initiative

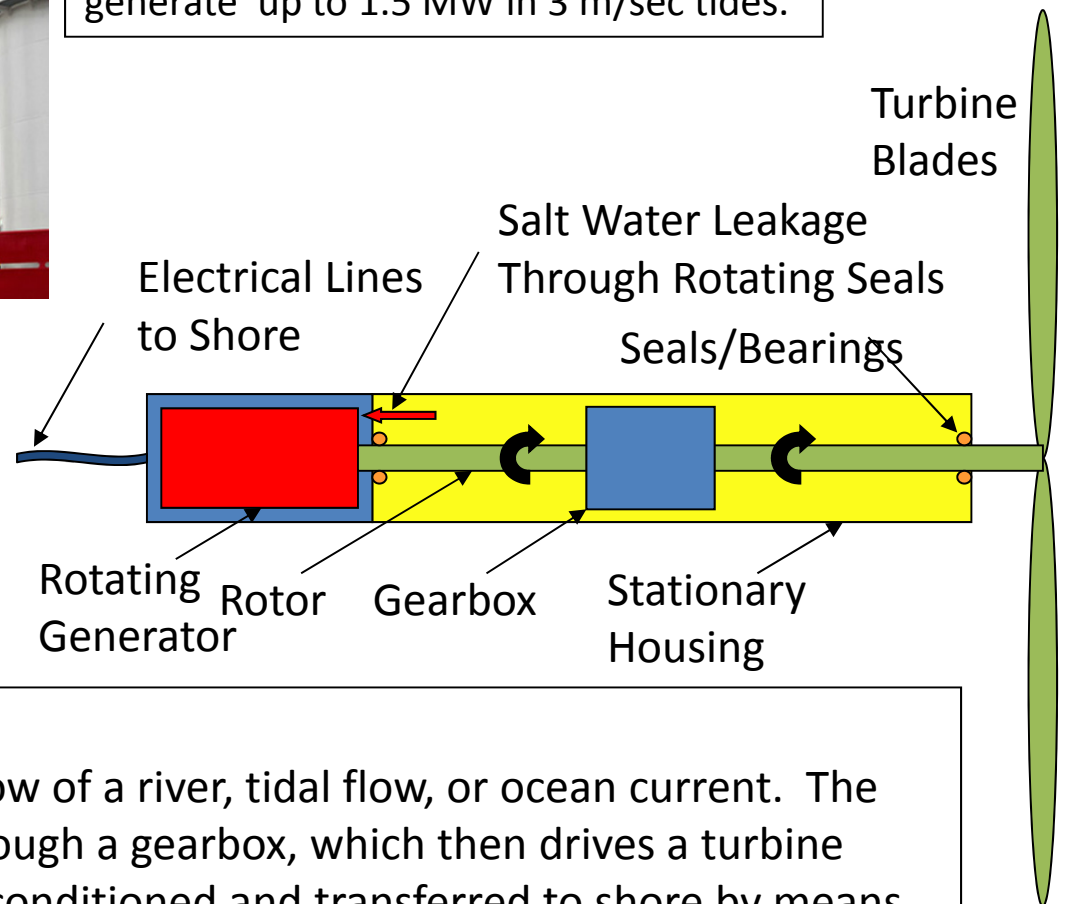


- DOE is funding research on “Tidal Energy System for On-shore Power Generation”
- Program Lead: Sunlight Photonics, South Plainfield, New Jersey
- Based on technology developed at NASA Jet Propulsion Lab, Caltech
- Partners include Atlantis Resources Corporation (Singapore), Maine Maritime Academy Tidal Energy Device Evaluation Center (TEDEC), and Rutgers University (New Jersey)
- Program Goals:
 - Demonstrate hydraulic transmission of 15 kW from simulated tidal energy for 2-m diameter blades in 3 m/sec tidal flow
 - Perform sizing and costing for a 15-25 MW commercial hydraulic tidal energy plant with on-shore power generation

BACKGROUND: CONVENTIONAL IN-STREAM TIDAL TURBINE



Atlantis Resource's 18-m blades can generate up to 1.5 MW in 3 m/sec tides.



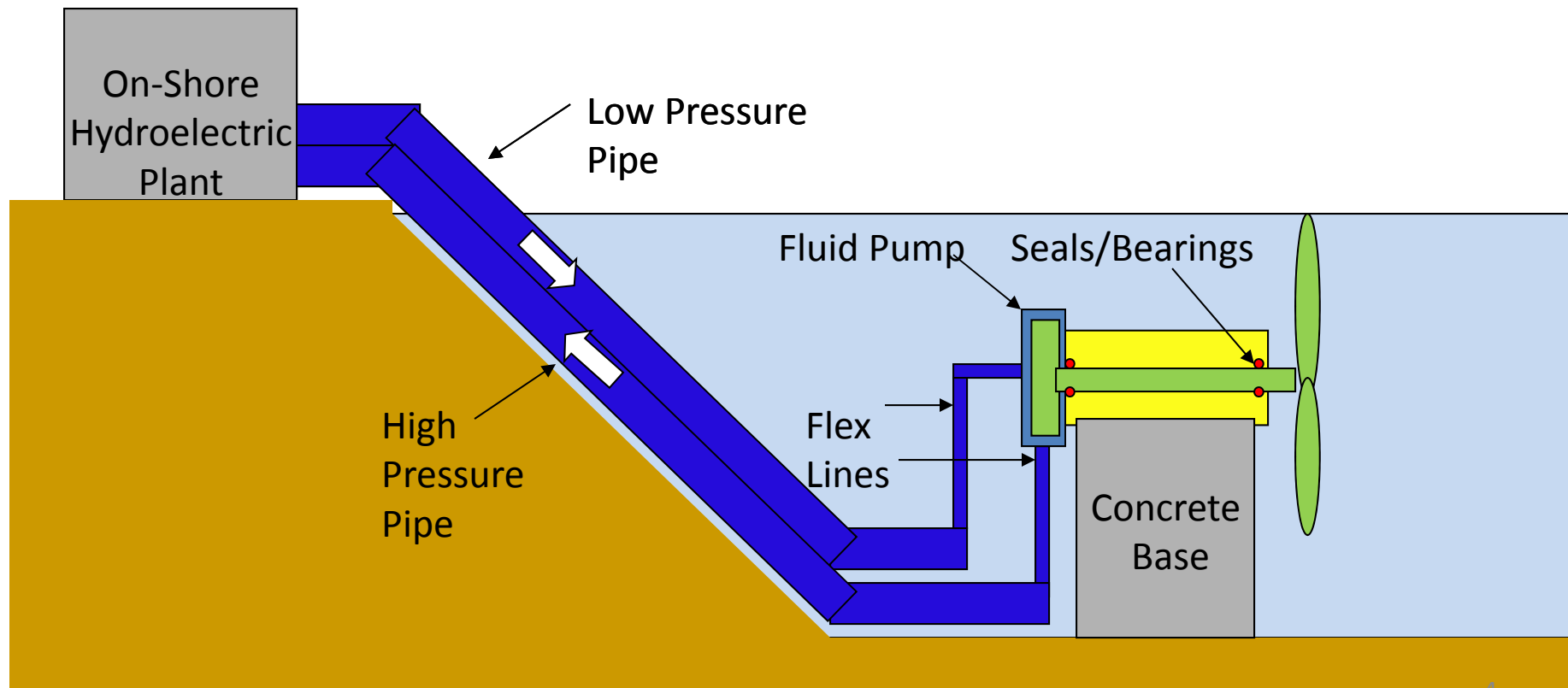
Device Operation:

Turbine blades spin slowly due to the flow of a river, tidal flow, or ocean current. The rotor's rotational speed is increased through a gearbox, which then drives a turbine generator. Each turbine output is then conditioned and transferred to shore by means of a buried electrical cable. ***This submerged electrical design is subject to salt-water corrosion of electrical components. Furthermore, the submerged cable and power conditioning are both expensive and dangerous, and the gears are subject to failure.***

JPL/CALTECH IMPROVED HYDRAULIC TIDAL TURBINE DESIGN

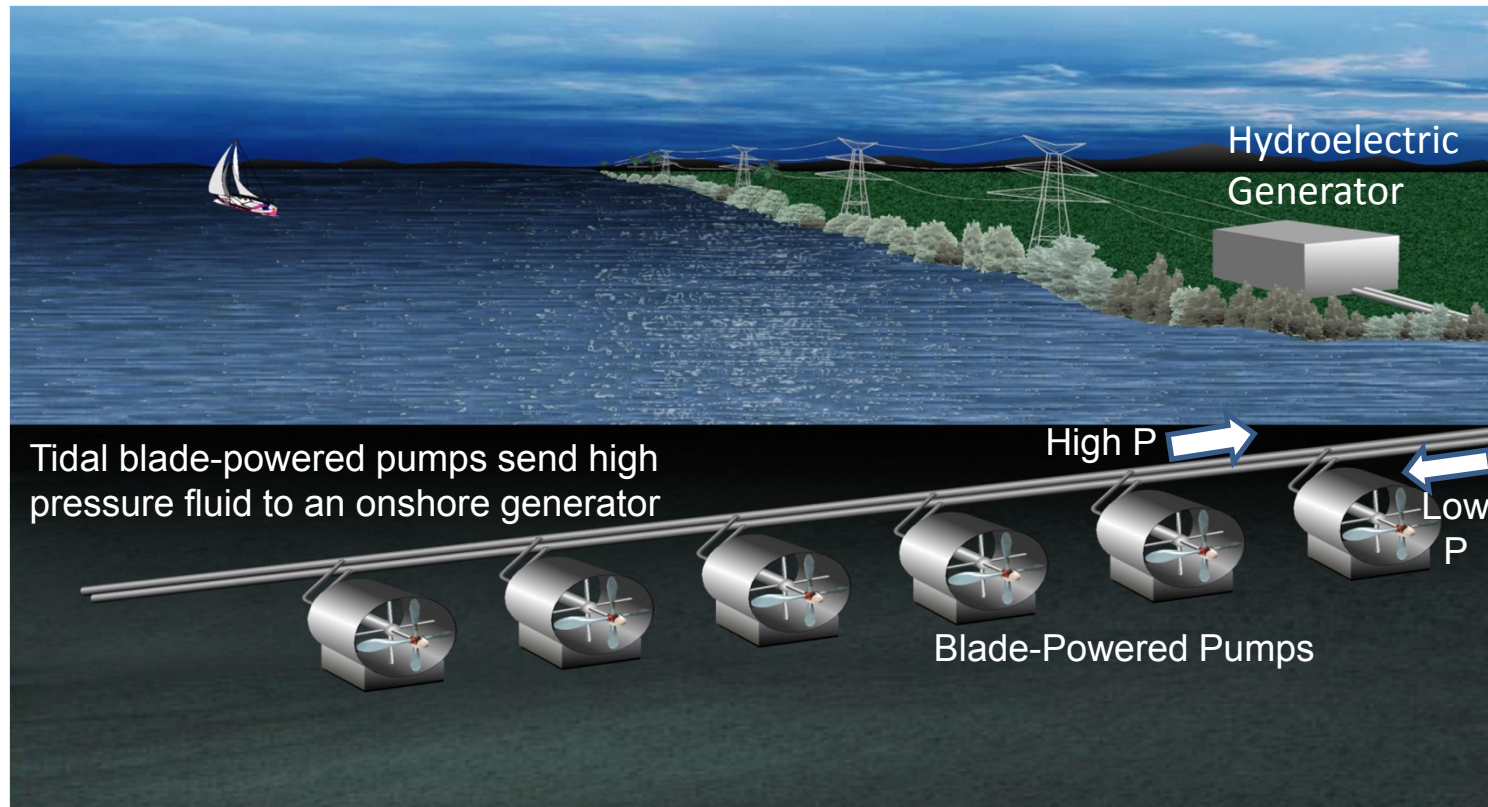
Device Operation:

Turbine blades spin slowly due to water currents. The rotor's rotational speed is transmitted directly to a commercially-available, high pressure fluid pump, without any gears. The high pressure fluid, such as biodegradable vegetable oil, is transported in small flexible lines to a common stainless steel pipe and then to an efficient, on-shore hydroelectric power plant. ***This all-mechanical design is less expensive (JPL/UCLA study, 2007), more efficient, and eliminates all gears and submerged electrical component corrosion. A 500-m long, 0.35-m ID pipe at 3000 psi can efficiently deliver 15 MW of hydraulic power to shore.***



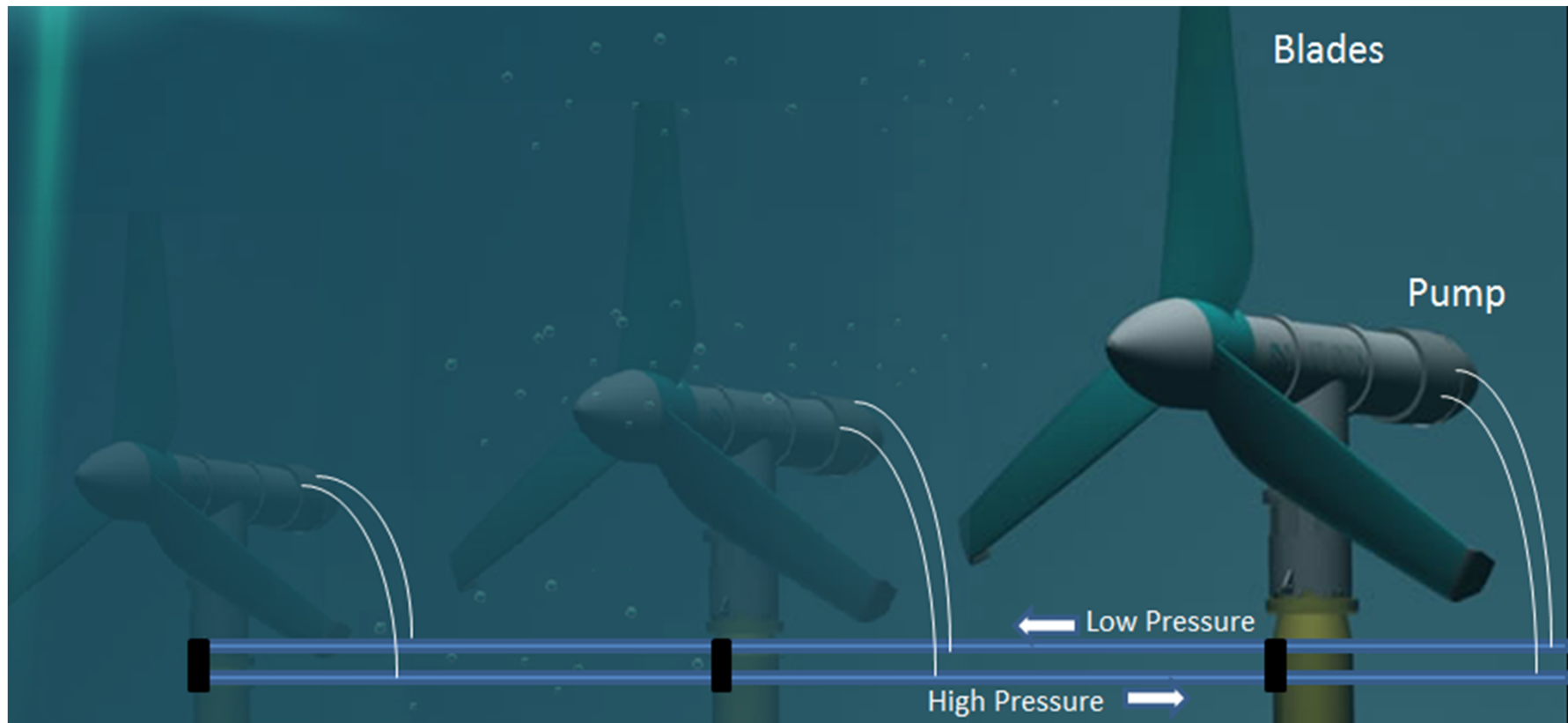


DOE PRESENTLY FUNDING JPL/CALTECH HYDRAULIC TIDAL TURBINE RESEARCH



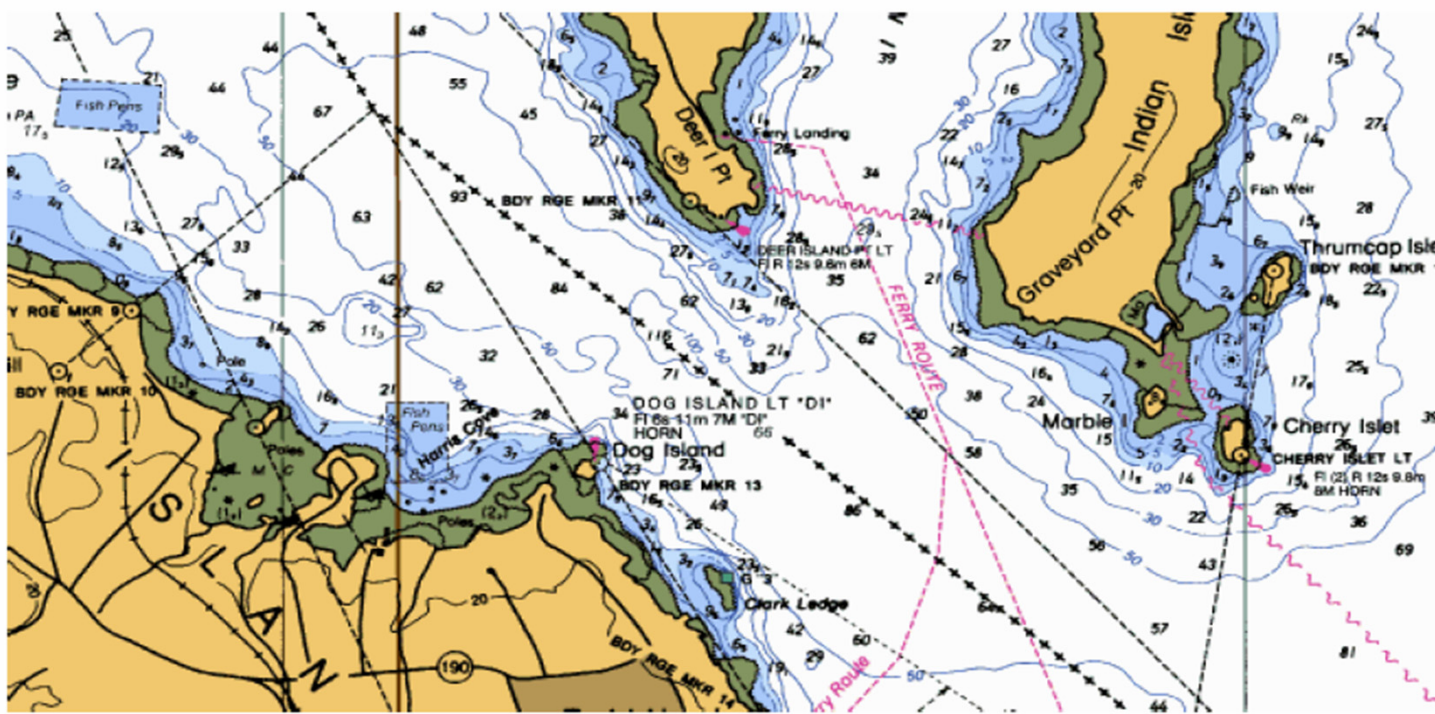
The DOE is presently funding JPL and Sunlight Photonics (FY'11-'12) to test a 15 kW hydraulic energy transfer tidal energy system that pumps environmentally-friendly, biodegradable vegetable oil to a remote, on-shore hydroelectric generator. A design is also being made for a 15 MW system in Maine's Western Passage tidal area. Both systems eliminate all gears and submerged electronics, thus greatly improving tidal energy reliability. Caltech has recently been granted patent rights to use this closed cycle hydraulic transfer design for tides, ocean currents, ocean waves, offshore wind, and onshore wind (US Patent 8,026,625)

ATLANTIS RESOURCE'S 15-M BLADES WITH HYDRAULIC ENERGY TRANSFER



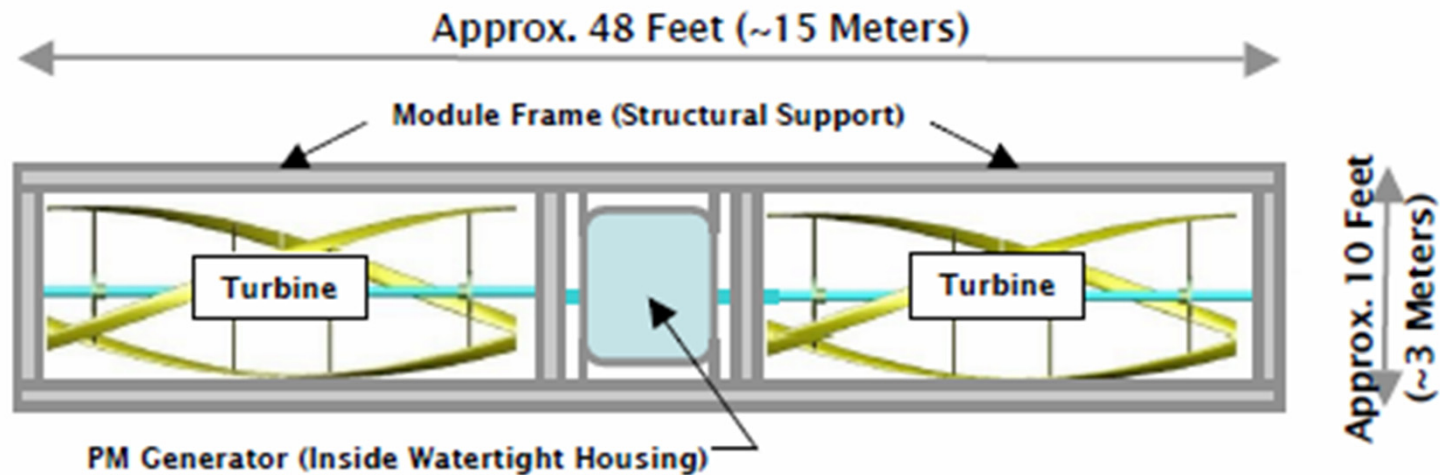
Fifteen of Atlantis Resource Corporation's 18-m blades can be used in Maine's Western Passage Tidal Area to generate 15 MW of tidal energy on-shore by means of using high pressure lines to transfer the energy to an on-shore hydroelectric plant.

MAINE'S WESTERN PASSAGE TIDAL AREA



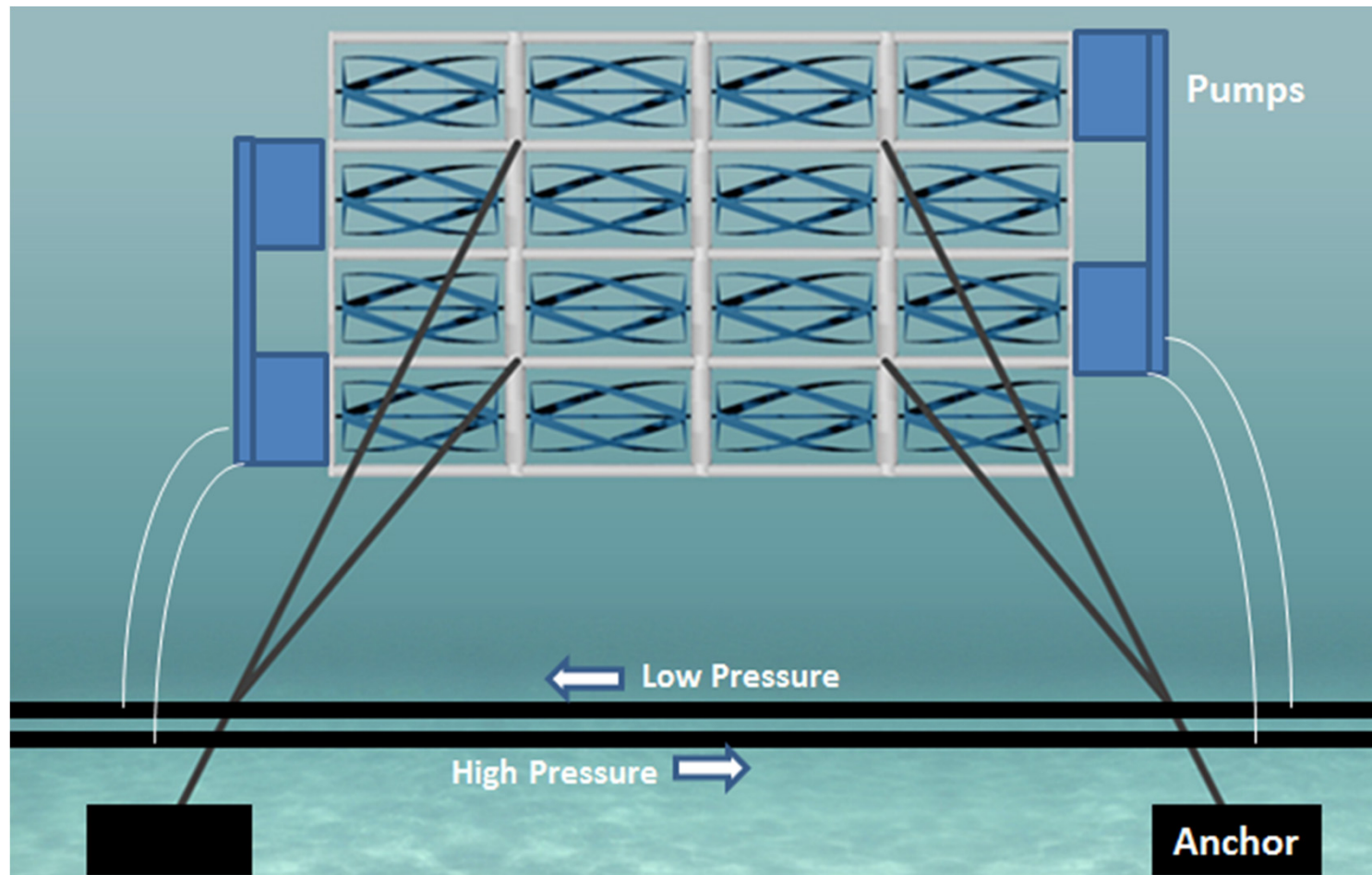
Maine's Western Passage tidal area straddles Canada to the north and Maine to the south. It is capable of producing at least 15 MW of tidal generated electricity.

ORPC CROSS-FLOW TIDAL GENERATOR



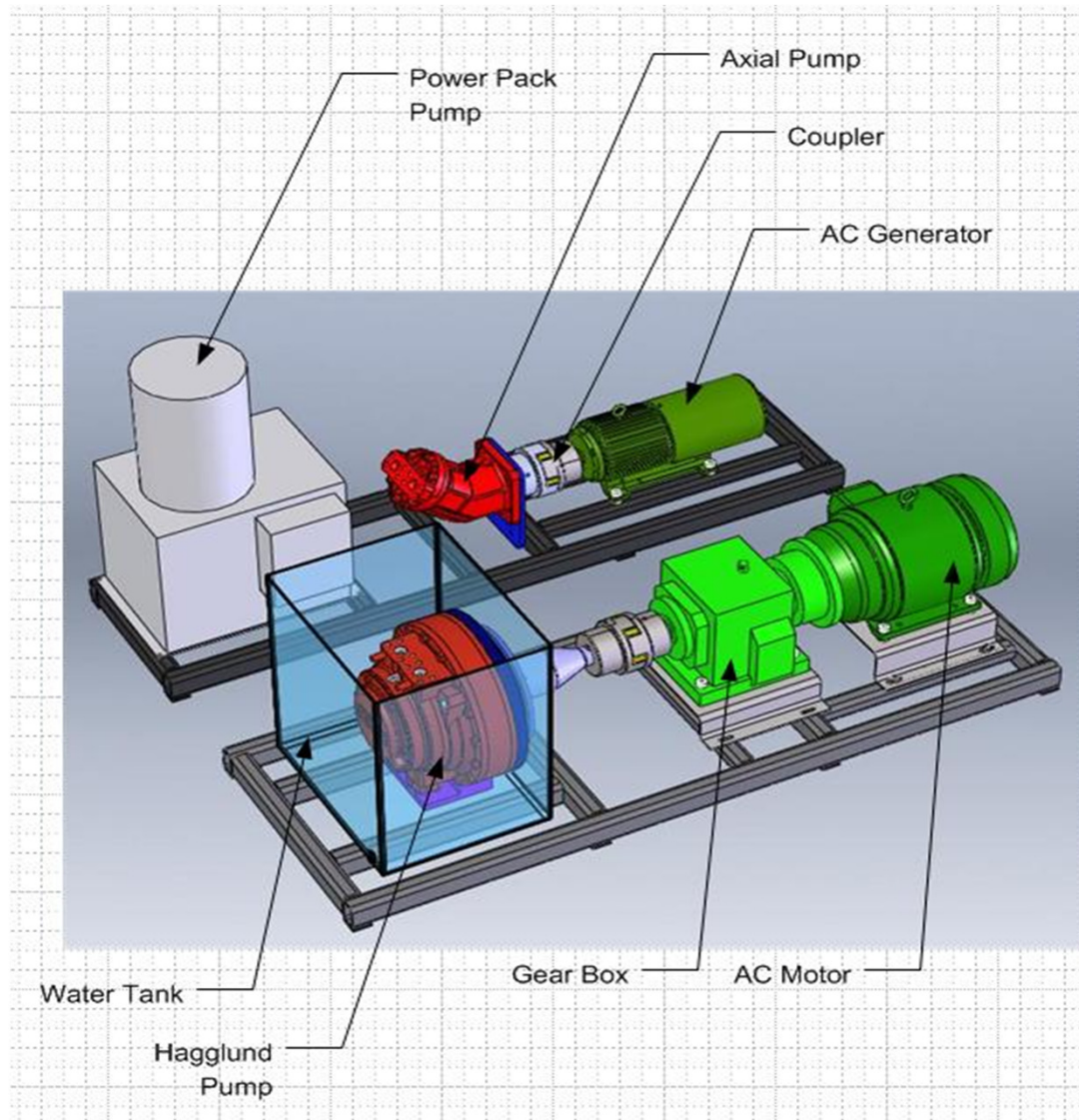
The Ocean Renewable Power Company (ORPC) is planning on installing cross-flow tidal generators in Maine's Western Passage. These turbines spin in the same direction regardless of tidal direction, and they require no gears. The generators, however, are potentially subject to water intrusion through rotating seals.

ORPC CROSS-FLOW TIDAL GENERATOR WITH HET



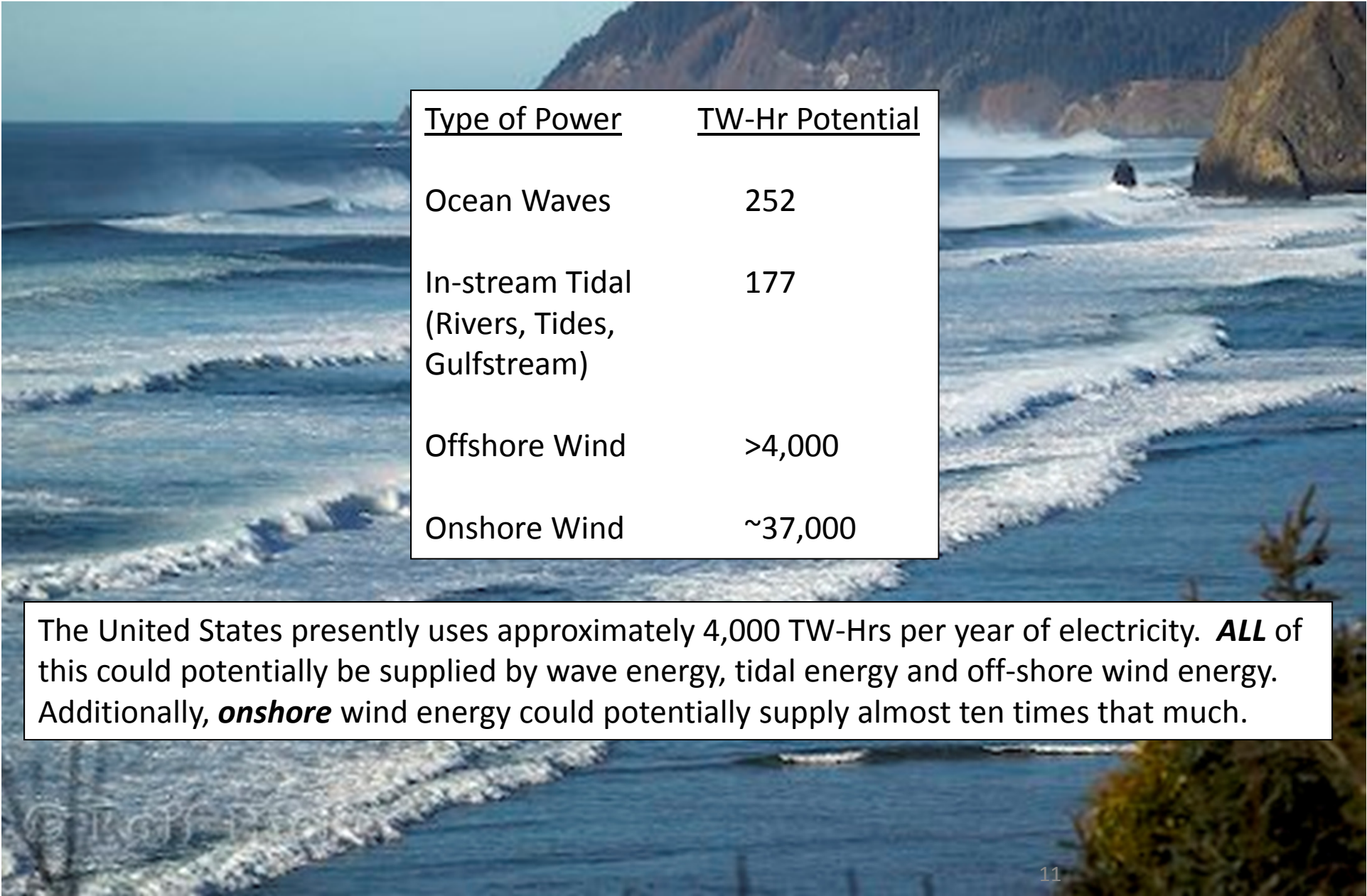
A 4x4 series of generators with hydraulic energy transfer could generate 4 MW of peak power in the Western Passage. Total hydraulic conversion cost for the ORPC system has been estimated to be about 50 cents per watt, minus the cost of the expensive submerged gearless generators, which would be eliminated.

RUTGERS UNIVERSITY HET TEST SETUP



Tests are currently being conducted at Rutgers University using a motor to simulate 15 kW of electricity from a conventional 2-m diameter blade. The motor torque turns a radial piston hydraulic pump, which pumps high pressure hydraulic fluid to an axial piston motor that turns a generator. Efficiency test results are anticipated soon.

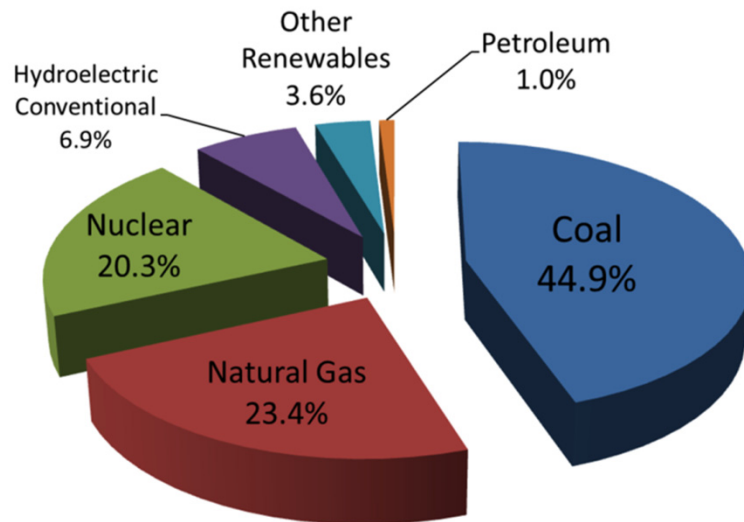
HYDROKINETIC AND WIND ENERGY PRODUCTION POTENTIAL



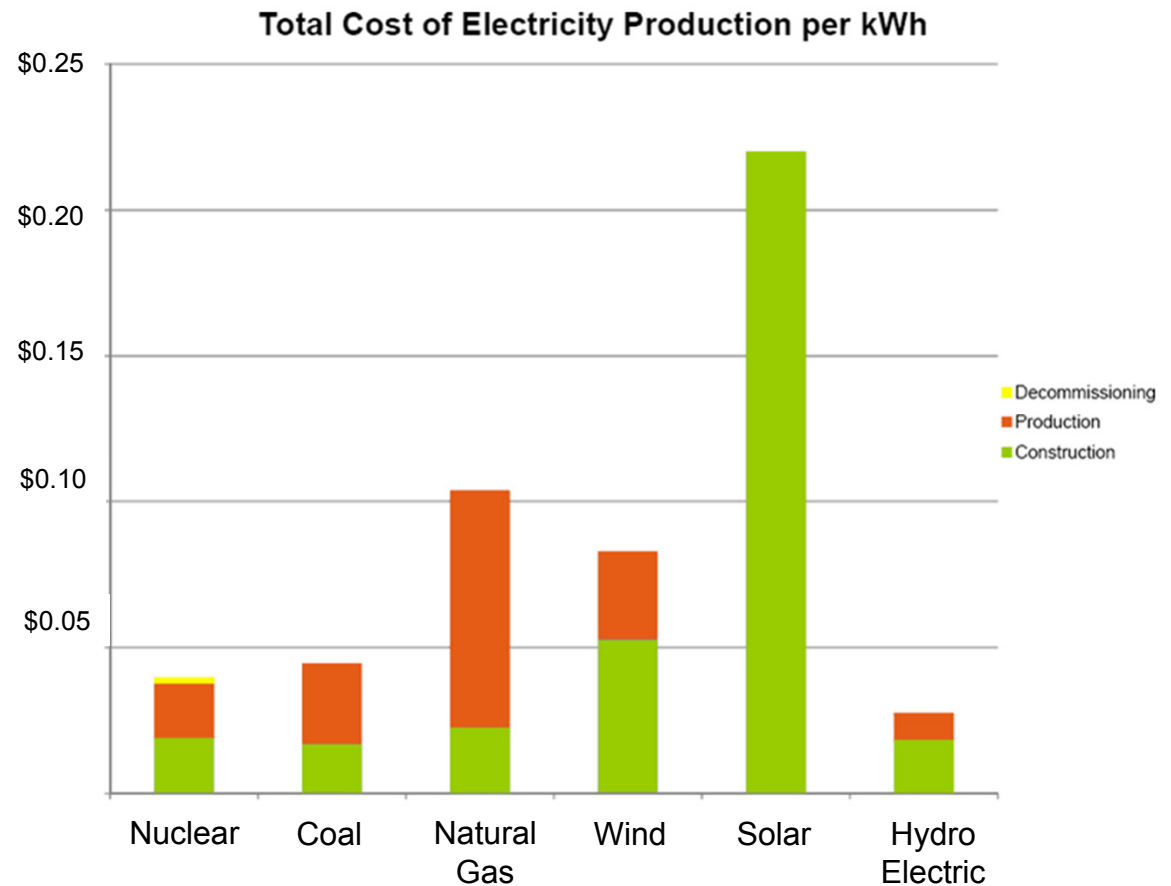
<u>Type of Power</u>	<u>TW-Hr Potential</u>
Ocean Waves	252
In-stream Tidal (Rivers, Tides, Gulfstream)	177
Offshore Wind	>4,000
Onshore Wind	~37,000

The United States presently uses approximately 4,000 TW-Hrs per year of electricity. **ALL** of this could potentially be supplied by wave energy, tidal energy and off-shore wind energy. Additionally, **onshore** wind energy could potentially supply almost ten times that much.

US ELECTRICAL PRODUCTION AND COSTS

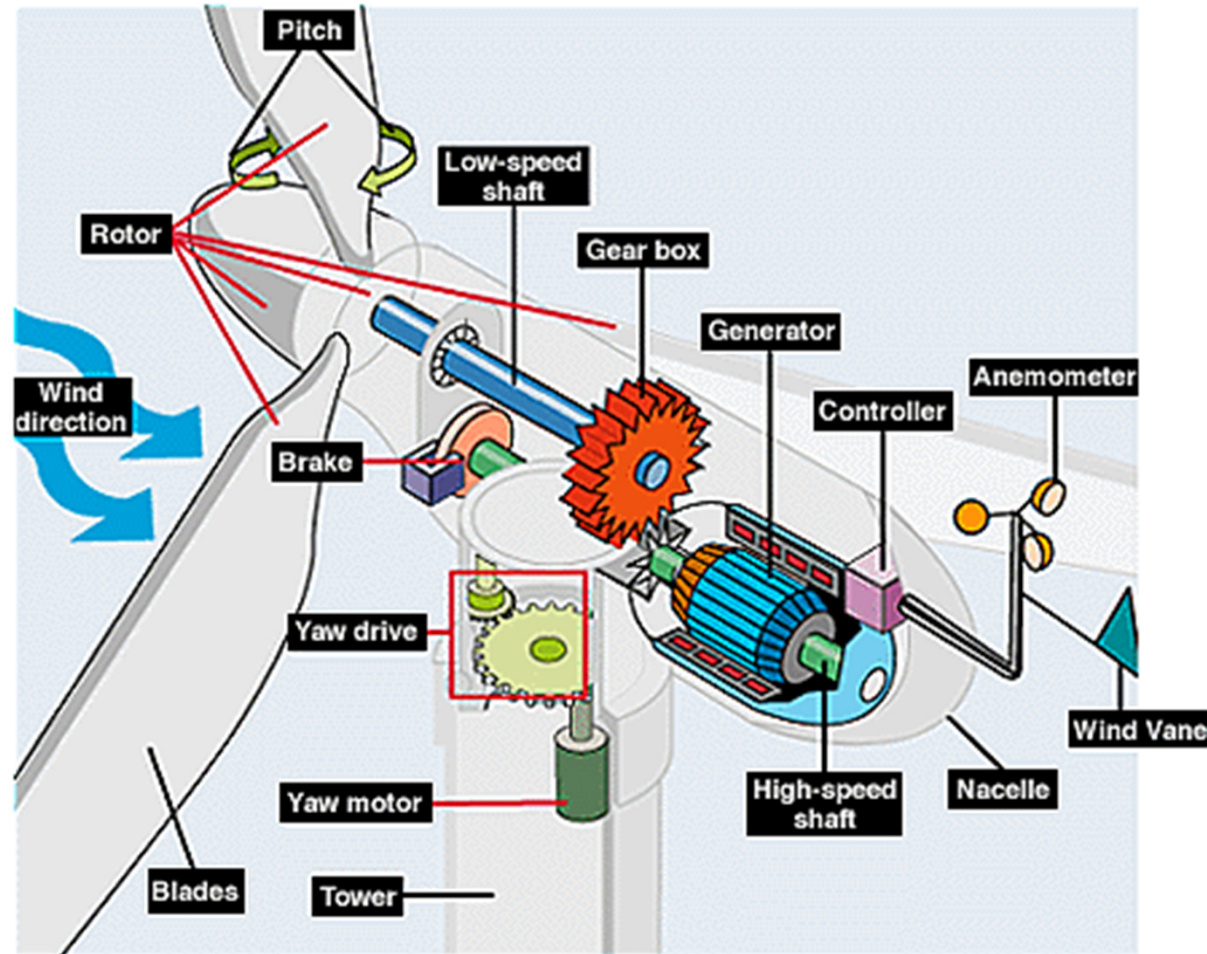


2009 US Electricity Production



Hydraulic tidal energy costs have been estimated at about \$0.14 per kWh, which is between natural gas and solar.

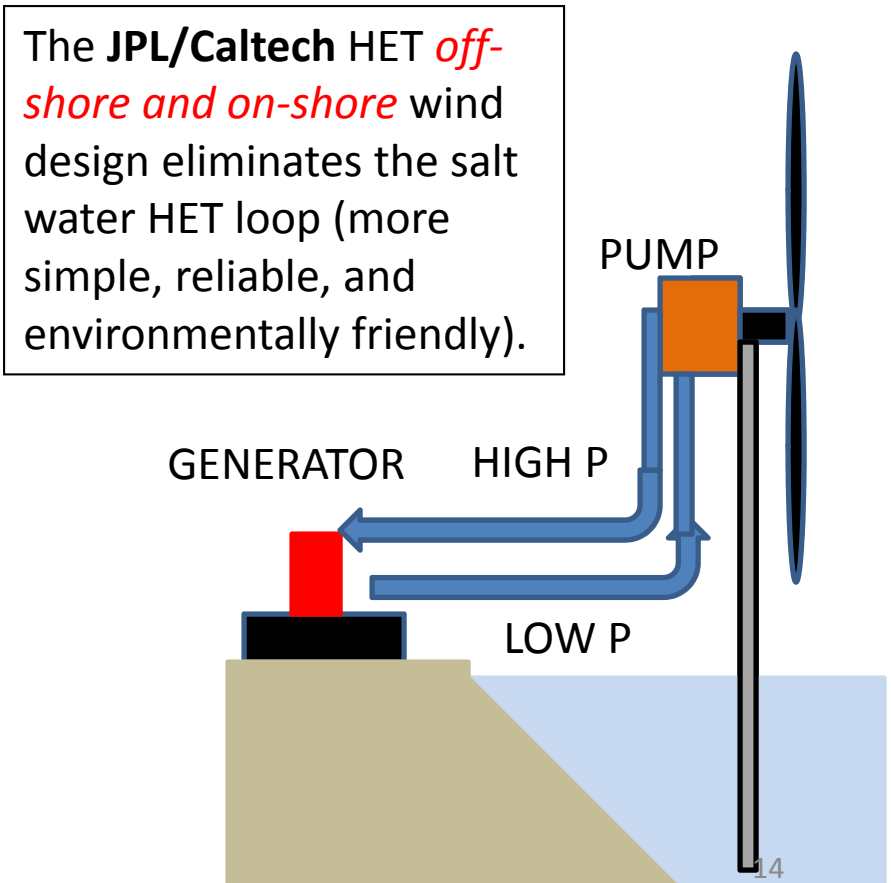
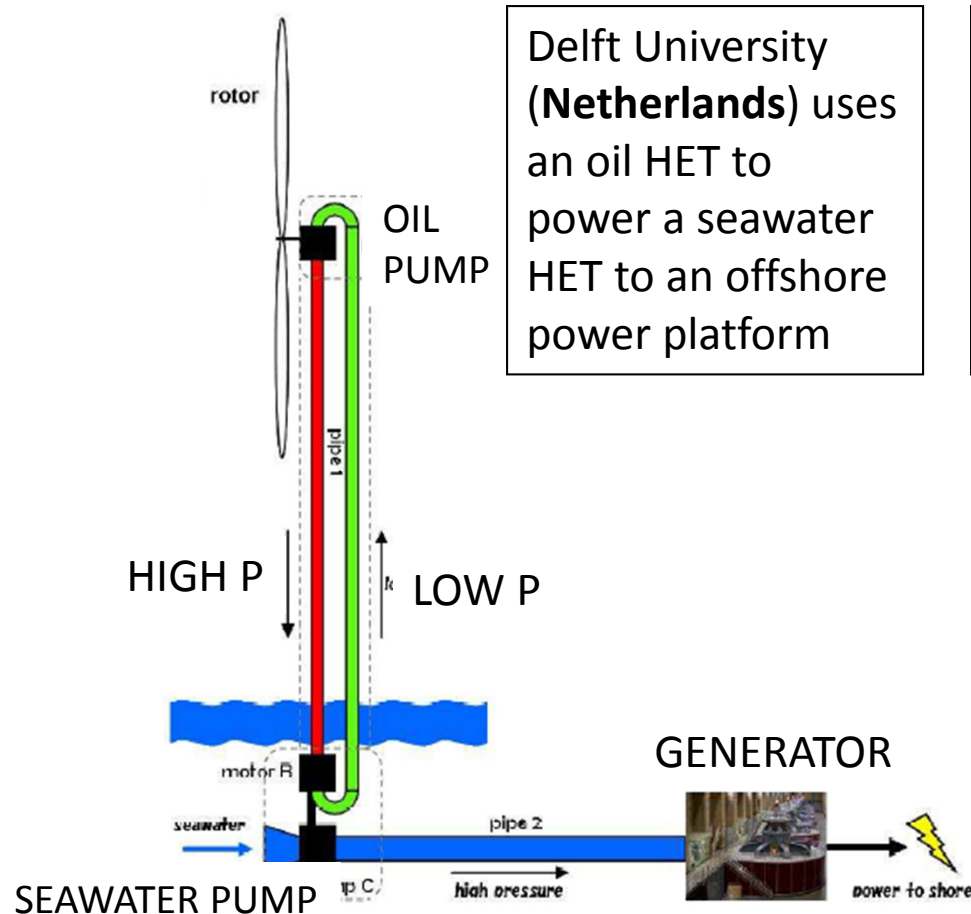
CONVENTIONAL WIND TURBINE DESIGN



In the conventional wind turbine, a set of gears increases the RPM to the generator, which generates electricity. The gears represent a frictional loss that is very significant at lower speeds. The gears are also the most likely component to fail. Repairing gears or the generator requires expensive off-time to service the upper part of the wind turbine.

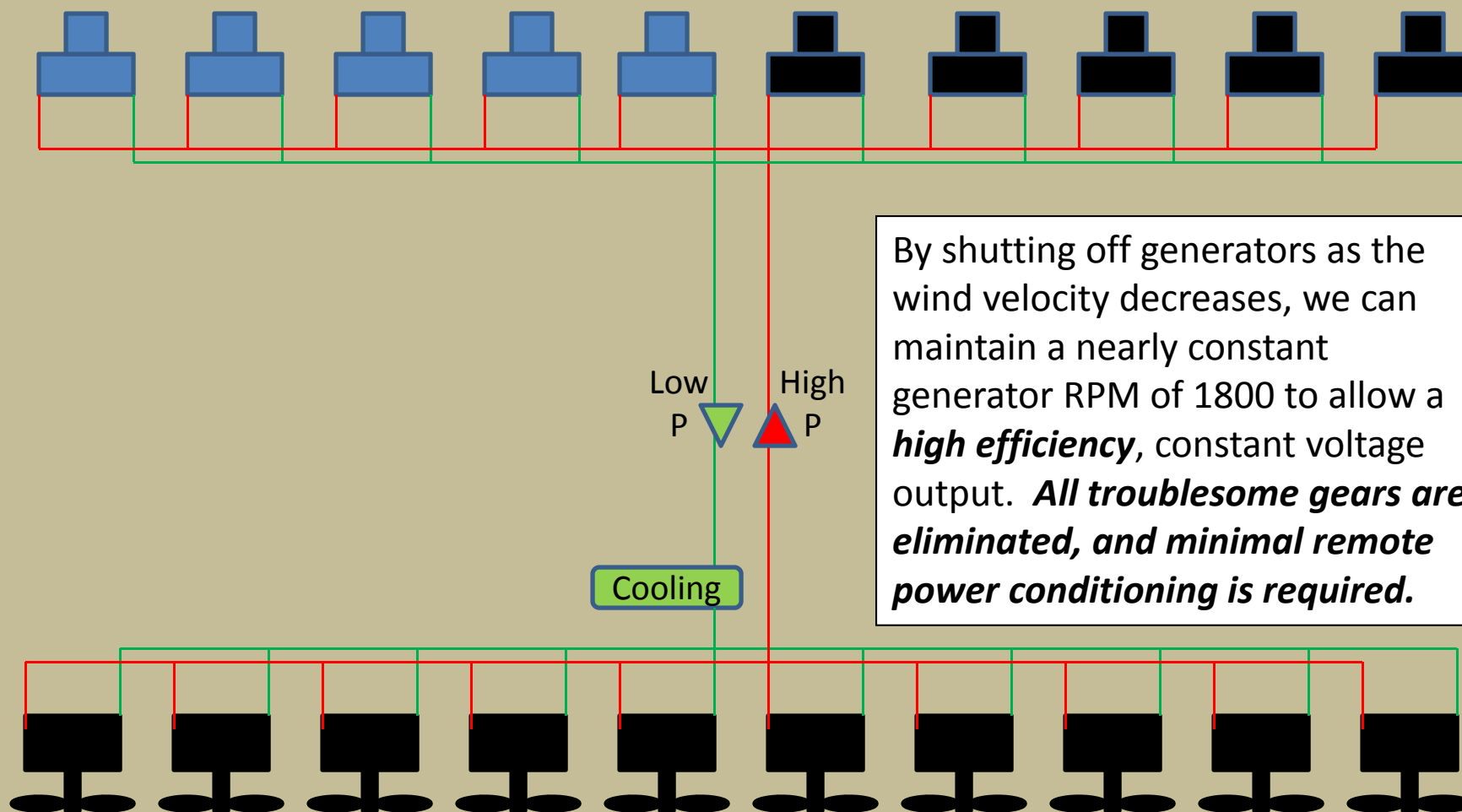
WIND TURBINE HYDRAULIC ENERGY TRANSFER (HET) **JPL**

There are three European companies (Chap Drive/**Norway**, Artemis/**Scotland**, and Voith Turbo WinDrive/**Germany**) that have replaced top-mounted, wind turbine gears and generator with more reliable and efficient, top-mounted hydraulic pumps, with complicated generators at the base. Two other HET systems to transfer energy remotely are shown below.



Onshore Wind Turbine Power Generation

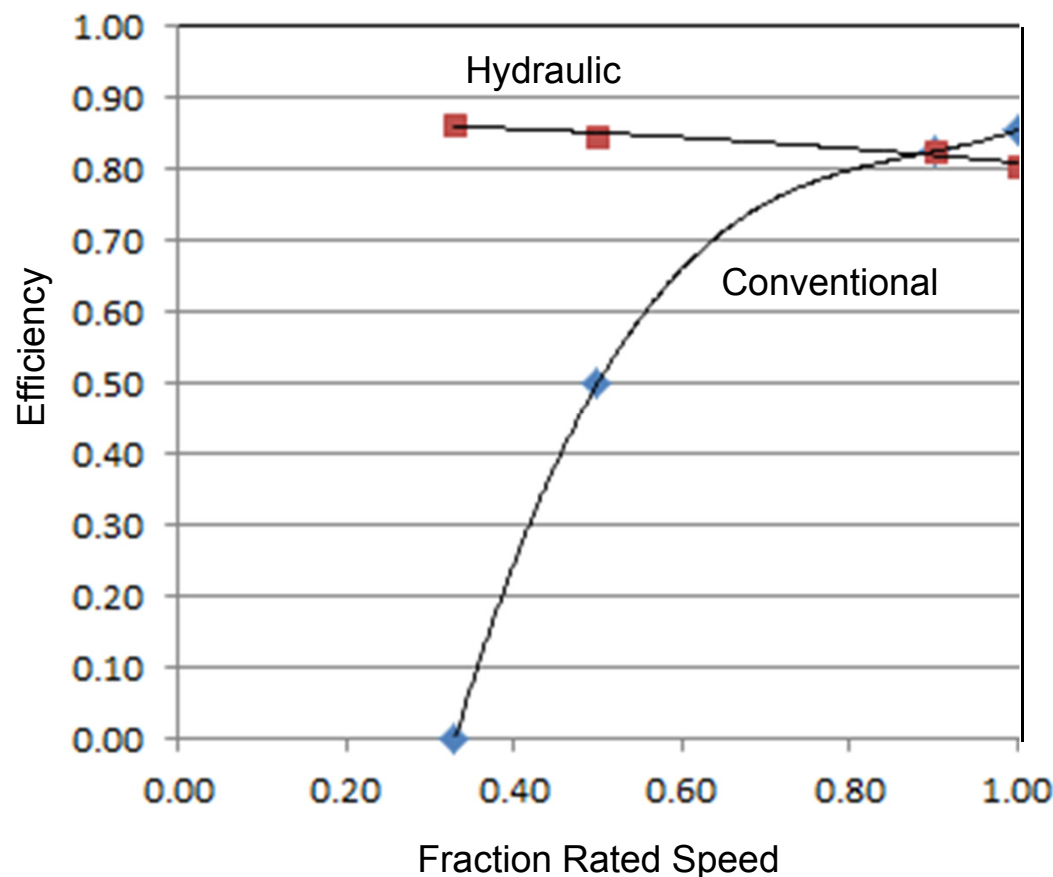
Remote Radial Piston Hydraulic Generators (~15 MW)



Blade Diameter = 58-m
RPM=18 at Max Velocity

Wind Turbine Radial Piston Hydraulic Pumps
(Fifteen Units, Bosch MB2400 @ 1.0 MW = 15 MW)

Blade-to-Grid Power Wind Turbine Efficiency

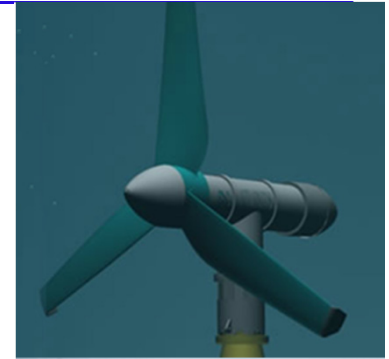


At speeds below about 90% of rated speed, the hydraulic energy transfer system is more efficient than conventional wind turbines. Conventional wind turbines drop efficiency fast due to generator and gearbox efficiencies, while hydraulic wind turbines increase pump and pressure drop efficiencies with lower speeds, while keeping generator efficiencies constant by dropping out unused generators.

HYDRAULIC ENERGY TRANSFER DESIGN ADVANTAGES



- All failure-prone gears are eliminated, and the electronics are moved to a central, more easily maintained, ground-level power generating station.
- Nearly constant generator RPM results in higher efficiency power.
- Power conditioning required at central generator only, not at each distant blade unit.
- Uses small amounts of environmentally-friendly, biodegradable vegetable oil for both offshore wind and onshore wind systems.
- Similar hydraulic power transfer systems can be used with offshore tides, ocean currents, ocean waves, offshore wind and onshore wind.



Abstract Submitted to Renewable Energy World Conference 2012
On-Shore Power Generation for Off-Shore Tidal and Wind Energy



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Tidal energy, offshore wind energy, and onshore wind energy can be converted to electricity at a central ground location by means of converting their respective energies into high-pressure hydraulic flows that are transmitted to a system of generators by high-pressure pipelines. The high-pressure flows are then efficiently converted to electricity by a central power plant, and the low-pressure outlet flow is returned. The Department of Energy (DOE) is presently supporting a project led by Sunlight Photonics to demonstrate a 15 kW tidal hydraulic power generation system in the laboratory and possibly later submerged in the ocean. All gears and submerged electronics are completely eliminated.

A second portion of this DOE project involves sizing and costing a 15 MW tidal energy system for a commercial tidal energy plant. For this task, Atlantis Resources Corporation's 18-m diameter demonstrated tidal blades are rated to operate in a nominal 2.6 m/sec tidal flow to produce approximately one MW per set of tidal blades. Fifteen units would be submerged in a deep tidal area, such as in Maine's Western Passage. All would be connected to a high-pressure (20 MPa, 2900 psi) line that is 35 cm ID. The high-pressure HEPG fluid flow is transported 500-m to on-shore hydraulic generators. HEPG is an environmentally-friendly, biodegradable, water-miscible fluid. Hydraulic adaptations to ORPC's cross-flow turbines are also discussed.

For 15 MW of wind energy that is onshore or offshore, a gearless, high efficiency, radial piston pump can replace each set of top-mounted gear-generators. The fluid is then pumped to a central, easily serviceable generator location. Total hydraulic/electrical efficiency is 0.81 at full rated wind or tidal velocities and *increases* to 0.86 at 1/3 rated velocities.